NASA TN D-370

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TECHNICAL NOTE

D-370

HELICOPTER-ENGINE ACCELERATION-TIME REQUIREMENTS BASED ON PILOT DEMAND DURING RECOVERY FROM LANDING FLAREOUTS

By Andrew B. Connor

Langley Research Center
Langley Field, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON May 1960

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SUMMARY

To provide information on response requirements of helicopter engines, flight measurements are presented showing the times used by pilots to accelerate an engine from low to full power in a maneuver considered to make the greatest demand on engine-response time. The results show that pilots used from 3.0 to 5.1 seconds in a lightweight helicopter and 3.0 to 7.6 seconds in a mediumweight helicopter.

INTRODUCTION

Some types of turbine engines are known to accelerate from low to full power at a much slower rate than reciprocating engines. In considering the application of turbine engines to helicopters, inquiries have arisen as to whether their acceleration rates could impose some operating limits on the helicopter.

Flight tests were conducted at the Langley Research Center to gain some insight into whether engine-acceleration capability might operationally limit a helicopter. Also, a VGH survey of a helicopter pilot-training operation was analyzed in this connection. The NASA (formerly NACA) VGH recorder furnishes time histories of airspeed, center-of-gravity normal acceleration, and altitude. The results of the tests and survey analysis are presented to show the extent to which the pilots make use of engine acceleration from low to full power under maneuver conditions. The recovery from a flareout following an autorotative or low-power descent is the most critical maneuver from the standpoint of engine response. Therefore, the results presented are for this maneuver only.

TEST HELICOPTERS AND PROCEDURE

The helicopter shown in figure 1 has a normal gross weight of approximately 2,300 pounds. It has the usual instrument panel display and, additionally, an instantaneous rate-of-climb meter. The helicopter shown in figure 2 has a normal gross weight of approximately 6,700 pounds. This helicopter was fully instrumented with NASA recording instruments equipped with synchronized timers. The military pilot-training helicopter from which the VGH survey data were obtained is similar to the helicopter in figure 1.

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The maneuver used in the tests was the recovery following a flareout from a low power or autorotative descent. In the opinion of NASA pilots the greatest demand for rapid engine response is in the execution of this maneuver. Primarily, measurements were taken of the time that the pilots used to accelerate the engine in executing the recovery; secondarily, the flight conditions under which the maneuver was executed were noted.

In the NASA flight test with the lightweight helicopter shown in figure 1, an observer recorded the flight conditions of the maneuver and timed the pilot's control of the engine during recovery. In the medium-weight helicopter, time histories of the flight conditions and the pilot's engine-control settings were obtained by recording instrumentation. These time histories provided characteristic curves of the flight-test maneuver and facilitated the analysis of the VGH survey records of the military training operations.

RESULTS

Engine-Acceleration Times in the Lightweight Helicopter

The flight-test results obtained with the lightweight helicopter shown in figure 1 are presented in table I. The table lists the conditions prior to the maneuver with each measurement of the time interval used by the pilot to accelerate the engine. One factor that was not measured was height above ground at which the flareout was initiated. However, in all cases the height appeared to be such that, upon termination of the flareout, recovery was executed in the ground-effect region. As shown in table I, the engine-acceleration times used by the pilot ranged from 3.0 to 5.1 seconds.

Four quick-stop maneuvers were also executed because they require a flareout and recovery similar to that in autorotations. However, in a quick-stop maneuver the engine is not disengaged from the rotor as in autorotations, and the required increase in power is less. Even in these maneuvers the pilot used from 3.1 to 4.8 seconds to attain full power.

Four autorotations to landing were timed to determine whether sinking times from initiation of recovery to touchdown were compatible with the engine-acceleration times. The sinking times ranged from 2.3 to 4.5 seconds.

Engine-Acceleration Times in the Mediumweight Helicopter

Table II lists the results obtained from the flight test with the fully instrumented helicopter shown in figure 2. All the approaches terminated in hovering, and the conditions prior to each approach are listed with the timed results. The time that the pilot used to control the engine during the recovery was measured from the collective-pitch-control and manifold-pressure records. The manifold-pressure record indicates how much time was used by the pilot to take the engine to full power. The times recorded ranged from 3.0 to 7.6 seconds. The collective-pitch control, being linked directly to the throttle, also indicated when the pilot judged he had sufficient power. During the recovery the helicopter experiences a positive normal acceleration and a slight loss in rotor rotational speed. The rotor tachometer and normal-accelerometer records, therefore, indicate the maneuver simultaneously with the collective-pitch-control and manifold-pressure records. Typical time histories from these records are shown in figure 3. Also shown are time histories from the airspeed and longitudinal-cyclic-control records, which help to define the maneuver. The time histories of longitudinal cyclic control and collective-pitch control show that the pilot makes gradual rather than abrupt control motions.

Field-Survey Results

The VGH survey of the military pilot-training program, which was first reported in reference 1, was analyzed for autorotational approaches and recoveries from flareout. This analysis was undertaken to provide a comparison of pilot demand time for the same type of flare-out maneuver in military pilot-training operations and in tests made by NASA research pilots. All the recoveries analyzed were to touchdown, and the measured times indicate the interval available for engine acceleration. The results with conditions prior to the recovery are presented in table III. These times ranged from 2.5 to 10 seconds. Only three of the recoveries were timed at 2.5 seconds and all three were accompanied by a higher than normal landing acceleration increment. Rarely is the touchdown acceleration accompanying a normal landing in excess of a 0.5g increment.

DISCUSSION

The flight tests showed that the time interval during which the pilots will demand full acceleration from the engine has a minimum value. This minimum time is based on dynamic consideration of the helicopter. Even if a recovery were initiated at some condition that would result in a hard landing, the experienced pilot would not abruptly apply full power. In the opinion of NASA research pilots, the damage caused to the helicopter by abrupt controlling and sudden power application would most likely be more serious than the damage caused by premature impact during normal recovery technique.

The flight conditions of the maneuver are almost always controllable by the pilot. These conditions are approach speed, rate of descent, relative wind direction, and height above ground at which the recovery is initiated. The pilot is, therefore, usually able to allot time to the recovery according to the requirements of the maneuver and the characteristics of the helicopter and engine.

CONCLUDING REMARKS

Engine-response time demanded by the pilot was a function of the handling qualities of the helicopter and the flight conditions prior to the maneuver. The pilots used 3.0 to 5.1 seconds to accelerate the engine of a lightweight helicopter in the recovery that follows a flareout; they used a 3.0- to 7.6-second interval to accelerate the engine of a heavier helicopter in the same maneuver. A VGH survey of a military helicopter pilot-training operation showed that the student pilots normally used more than 3 seconds during the maneuver. In the three cases in which the students used less than 3 seconds, the touchdowns were accompanied by higher than normal landing acceleration increments. In these particular cases the student pilots may have been late in initiating the flareout. NASA research pilots were of the opinion that the damage caused to the helicopter by abrupt power application after an error in judgment would probably be more serious than the damage caused by premature landing impact if normal recovery technique were used.

A turbine engine which takes 3.0 seconds to get from low to full power would be expected to have satisfactory engine-response characteristics for lightweight and mediumweight helicopters.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., January 25, 1960.

REFERENCE

1. Hazen, Marlin E.: A Study of Normal Accelerations and Operating Conditions Experienced by Helicopters in Commerical and Military Operations. NACA TN 3434, 1955.

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TABLE I.- FLIGHT-TEST RESULTS FOR A LIGHTWEIGHT HELICOPTER

(a) Landing flareout times

Type of approach to hovering	Wind direction	Rate of descent, ft/min	Initial forward velocity, knots	Engine acceleration demand time, sec
Autorotative	Headwind	1,330	40	3.0
Autorotative	Headwind	1,330	40	3.0
Autorotative	Headwind	1,330	40	3.5
Autorotative	Headwind	1,330	20	5.1
Autorotative	Headwind	1,330	25	3.7
Quick stop	Headwind		40	3.6
Autorotative	Tailwind	1,380	40	5.0
Autorotative	Tailwind	1,380	40	4.9
Autorotative	Tailwind	1,330	20	3.5
Quick stop	Tailwind		40	4.8
Quick stop	Tailwind		40	3.2
Quick stop	Tailwind		50	3.1

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(b) Sinking times

Type of landing	Wind direction	Rate of descent, ft/min	Initial forward velocity, knots	Sinking time, sec
Autorotative to touchdown	Headwind	1,040	45	3.0
	Headwind	1,140	50	2.3
Autorotative run-on	Headwind	975	45	4.5
	Headwind	1,140	45	2.8

TABLE II.- FLIGHT-TEST RESULTS FOR A MEDIUMWEIGHT HELICOPTER

Type of approach to hovering	Wind direction	Rate of descent, ft/min	Initial forward velocity, knots	Engine acceleration demand time, sec, as indicated by -			
				Manifold pressure	Collective pitch	Rotor tachometer	Normal accelerometer
Autorotative	Headwind	975	50	5.0	5.8	5.6	4.9
Autorotative	Headwind	1,300	55	6.0	5.4	4.0	5.2
Autorotative	Left to right	1,050	40	5.9	4.9	4.0	4.5
Autorotative	Left to right	1,200	45	3.0	2.6	3.6	3.6
Autorotative	Left to right	1,050	40	3.7	4.7	5.8	6.1
Autorotative	Headwind	1,325	55	7.6	6.9	7.0	4.0
Autorotative	Headwind	1,250	45	7.2	7.8	6.8	8.3
Autorotative	Right to left	950	40	6.2	6.4	8.0	5.1
Autorotative	Right to left	1,100	25	7.1	5.5	4.8	4.5
Autorotative	Right to left	1,325	30	5.2	5.1	7.1	5.6
Quick stop	Headwind			5.2	4.9	4.3	7.4
Quick stop	Left to right			3.6	2.9	4.9	5.1
Autorotative	Headwind	1,075	50	5.5	7.3	5.5	4.3
Autorotative	Headwind	1,425	60	5.5	9.3	6.2	5.0
Autorotative	Headwind	1,175	55	5.8	6.4	5.0	5.4
Autorotative	Headwind	1,225	50	3.1	4.1	5.0	4.0
Autorotative	Headwind	1,500	50	6.0	6.5	3.5	7.0
Autorotative	Headwind	1,075	40	5.3	6.3	4.2	5.5
Autorotative	Headwind	1,425	25	5.0	5.5	6.3	5.2
Autorotative	Headwind	1,175	25	6.9	6.4	6.0	4.3
Autorotative	Headwind	1,600	25	6.0	7.4	4.8	3.5

TABLE III.- FLIGHT-TEST RESULTS FOR A LIGHTWEIGHT HELICOPTER FROM FIELD-INSTALLATION SURVEY

Rate of descent, ft/min	Maximum forward velocity, knots	Maneuvering time, sec
900	59	7.0
1,700	61	6.5
1,240	52	5.5
1,540	56	6.5
1,760	59	8.0
1,300	47	5.5
2,000	39	6.0
1,750	43	5.0
1,390	39	7.0
1,710	52	7.5
1,360	52	6.0
1,800	31	5.0
1,470	30	6.0
1,390	46	6.5
1,750	56	5.0
1,470	48	6.0
1,470	48	5.0
2,050	35	5.5
1,840	52	6.5
1,250	48	4.5
1,560	48	4.5
1,610	42	4.5
1,380	52	[a]2.5
1,750	48	[a]2.5
2,060	43	[a]2.5
2,200	43	7.5
1,500	50	7.5
2,060	48	4.5
2,000	47	4.5
1,800	56	4.5
1,220	35	3.5
1,760	56	6.5
1,040	56	3.5
1,820	47	7.5
2,080	48	6.5
1,580	56	3.5
2,400	43	6.0
1,090	39	6.0
2,400	52	10.0

[a]In these maneuvers landing acceleration increments exceeded 0.5g, the threshold value for normal landings.

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Figure 1.- Lightweight test helicopter. L-96950

Figure 2.- Mediumweight test helicopter. L-84196

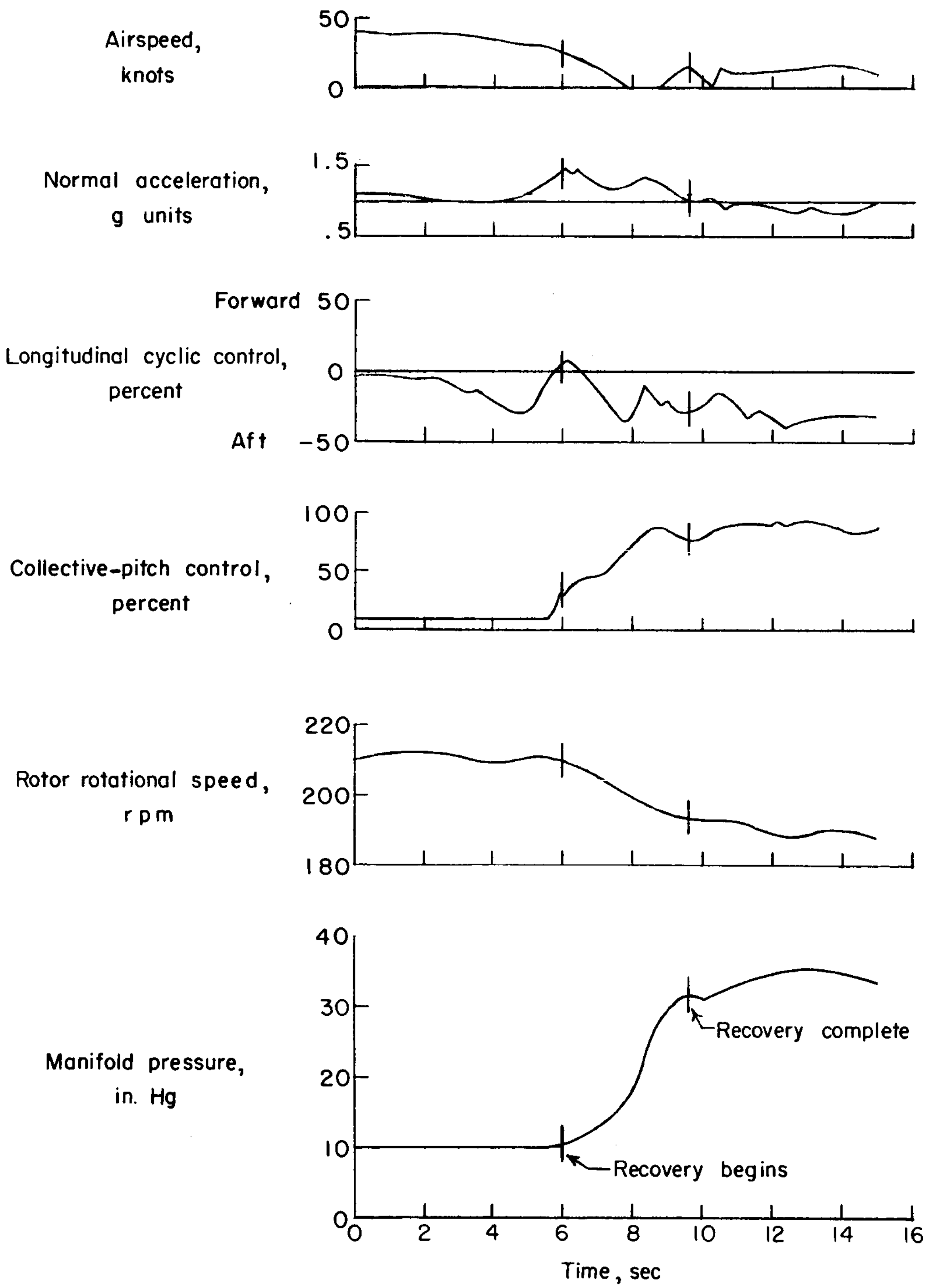

Figure 3.- Typical time history of the recovery from flareout for the mediumweight helicopter.